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Patent Claims

1. Spectral apparatus with several monochromatic receivers for the measurement of spectral light intensities of electromagnetic radiation in the visible and adjacent regions (IR and UV), is hereby characterized in that the light from a bundle of individual light guides [optical fibers] to be measured is collected and that monochromators, whose spectral transmissions are, at least in part, not equal to one another, are introduced each time at the light outlet sites of the multiple number of light guides, and each monochromator filters the respective light fraction of one light guide and introduces it to a light-sensitive receiver.

2. Spectral apparatus according to claim 1, further characterized in that the monochromators each possess a pre-focusing lens, at a focal point of which the light outlet site of a light guide is found, and the interference filters are introduced in the beam path behind the pre-focusing lens.

3. Spectral apparatus according to claim 2, further characterized in that interference filters and receivers have an approximately equal surface.

4. Spectral apparatus according to claim 1 and 2, further characterized in that the monochromators have a post-focusing lens between the interference filters

and the receivers each time, whereby the receivers are found in the focal points of the post-focusing lens.

5. Spectral apparatus according to one of claims 1-4, further characterized in that all light guides end bluntly in a polished surface at a light inlet site and the light inlet site is configured as planar or curved.

6. Spectral apparatus according to one of claims 1-5, further characterized in that the light guides are comprised of individual fibers, which are mixed such that the individual fibers of the individual light guides terminate in a distributed manner over the entire light inlet surface.

7. Spectral apparatus according to claim 6, further characterized in that some of the monochromators have the same spectral transmission and that the receivers, which are irradiated by spectrally identical monochromators, are connected in parallel.

8. Spectral apparatus according to one of the preceding claims, further characterized in that individual light guides possess different cross sections.

9. Spectral apparatus according to one of the preceding claims, further characterized in that the light guides are comprised of elastic material, e.g., glass fibers.

10. Spectral apparatus according to claim 9, further characterized in that the monochromators including the receivers are separated by chambers that are not transparent to light.

11. Spectral apparatus according to claim 10, further characterized in that light is introduced to a receiver from at least one light guide without the intermediate connection of a monochromator.

12. Spectral apparatus according to claim 11, further characterized in that the light inlet surface is found in the imaging plane of a serially connected lens system, which sharply images the light source to be measured onto the light inlet surface.

Spectral apparatus

The invention involves a spectral apparatus with several monochromatic receivers for the measurement of spectral electromagnetic radiation in the visible and the adjacent regions.

In fields of technology such as the dye and paint industry, metallurgy or organic chemistry, the task is frequently encountered of analyzing the composition of light spectra of direct, transmitted or reflected light, in order to be able to derive information on the nature of the material. It is also important to exactly determine the colors of materials, in order to be able to monitor their color constancy. It is often necessary to conduct repeated measurements on different objects in order to determine whether they have the same color quality.

So-called monochromators are used by the technician in order to solve this task. In a known type of apparatus, the light to be determined is deflected through a filter, which is only transparent to the light of a specific wavelength (e.g., interference filter, prism monochromator). The filtered light is then introduced into a photoreceiver and the photocurrent corresponding to the radiation intensity is measured. In order to measure the entire spectrum of a light source, filters with different spectral transmissions are sequentially used in this apparatus, and the respective radiation flux is measured. Since such measurements are very time-consuming, e.g., in order to be able to derive reliable information on the

spectral distribution, a measurement must be conducted every 10 nm with such a filter in the wavelength range from 380 to 780 nm. In order to shorten the time for the measurement, spectral apparatuses are also known, in which all of these interference filters are attached to a rotating disk, so that the light falls sequentially on the interference filters and from there is conducted to a photocell by means of a mirror system.

However, since the spectra of auto-emitters are usually not similar to one another in the case of different luminosities, errors must be taken into the bargain in these spectral apparatuses, since the luminosities can fluctuate greatly in the course of the measurements.

It is attempted to avoid this disadvantage with other spectral apparatuses.

For example, an arrangement has become known in which a multiple number of monochromators, each with their own photoreceiver, are used. In the case of these monochromators, interference filters are also used, which are found, however, in front of the light-sensitive surface of the photocell. Monochromators and photocells are arranged in two planes parallel to one another. If the spectral apparatus is irradiated with light, the quantities to be measured corresponding to the spectral components can be derived simultaneously in parallel at the photocells. The spectral devices, however, have the disadvantage that if the receiving or collecting surface is very large, the individual interference filters will

shift their transmission maxima to smaller wavelengths in the case of oblique light incidence or in the case of larger inlet apertures according to the equation:

$$\lambda(\alpha) = \lambda_0 \sqrt{n^2 - \sin^2 \alpha}$$

The measurements will be false in the case of oblique light incidence. An interference filter operates in a spectrally pure manner only in the case of parallel light incidence.

In the case of this spectral apparatus, this [parallel incidence] is not provided, however. Essentially undirected light impinges here, since the collecting surface is very large.

It has already been attempted to reduce the dimensions of the light inlet surface, in which the light to be measured is deflected by a rotating mirror to monochromators, which are arranged in one plane.

The object to be measured is imaged sharply on the monochromators by a focusing lens found in the vicinity of the mirror. In this type of device, in fact, the purity of the individual spectral components of the light, which are collected by the photocells, increases again, but here the spectral components of the light again cannot be measured a parallel, but rather sequentially according to the speed of rotation of the rotating mirror. Also, this spectral apparatus is not maintenance-free due to moving parts and is thus susceptible [to failure].

The object of the invention is now to avoid all of the named disadvantages of the known spectral apparatuses of the prior art and to create a simple and robust device without moving parts, which has a high spectral purity but which, however, possesses a high sensitivity directly in low-light wavelengths. Also, it will also permit the precise measurement of objects with very small dimensions.

According to the invention, this problem will be resolved in the case of a spectral apparatus with several monochromatic receivers for the measurement of spectral electromagnetic radiation in the visible and adjacent regions (IR and UV) in that the light to be measured will be collected by a bundle of individual light guides [optical fibers], and that monochromators, whose spectral transmissions are not equal to one another, at least in part, are introduced each time at the light outlet sites of the multiple number of light guides, and the respective light fraction of one light guide is filtered by each monochromator and is introduced each time into a light-sensitive receiver.

A favorable design of a spectral apparatus can be seen in that each monochromator possesses a pre-focusing lens, at the focal point of which the light outlet site of a light guide is found, and that interference filters are introduced in the beam path behind the pre-focusing lens.

A favorable configuration can be seen in the fact that the monochromators have a post-focusing lens between the interference filters and the receivers each time, whereby the receivers are found in the focal points of the post-focusing lenses.

An equally favorable configuration can be seen in that all light guides terminate bluntly in a polished surface at a light inlet opening and the light inlet site is configured in a planar or curved manner.

An advantageous configuration is then present, if the light guide is comprised of individual fibers, which are mixed in such a way that the individual fibers of the individual light guides are distributed over the entire light inlet surface.

An advantageous configuration is then also present according to the invention, if a portion of the monochromators have identical spectral transmission, and if the receivers, preferably photocells, which are irradiated by spectrally identical monochromators, are connected in parallel.

A spectral apparatus is also advantageous, in which individual outlet light guides possess different cross sections. Further, a spectral apparatus is favorable, in which the light guide is comprised of elastic material, preferably of glass fibers.

A spectral apparatus is also favorable, in which the monochromators including the receivers are separated by chambers that are not transparent to light.

Another favorable configuration is then present, if light is introduced into one receiver from at least one light guide without the intermediate connection of monochromator.

Lastly, an advantageous design is present according to the invention, if the light inlet surface is found in the imaging plane of a serially connected lens system, which sharply images the light source to be measured onto the light inlet surface.

Spectral apparatuses according to the invention are advantageous due to the high spectral purity of the individual radiation fractions falling on the photoreceivers, which is made possible due to the practically parallel beam path of the light fraction through the interference filter. The light fraction that [is found] at the light outlet site of the light guide, also in the case of parallel light incidence, is broadened practically into a club shape and is directed in parallel by the focusing lens, so that undirected light can no longer fall on the interference filters. Also, it is no longer necessary to be careful that the light to be measured falls perpendicularly and/or parallelly onto the light inlet surface of the light guide bundle, since the club-shaped light fraction also forming obliquely to the light output surface is directed through the focusing lens found in front of the interference filter [and] passes through the filter.

Due to the directed radiation, it is no longer necessary to arrange the interference filters exactly perpendicular to the optical axis, since the spectral purity is not adversely affected; the transmission maximum is shifted to lower wavelengths. The focusing lenses found behind the interference filters make it possible to use small photocells with small capacities, so that as a consequence of this, the photocells can be scanned very rapidly by sequential circuits. Also, the sensitivity of the spectral apparatus can be appropriately increased in low-light wavelength regions by parallel connection of several photocells. The monochromators of these photocells, of course, have the same spectral transmission.

If the outlet light guides of a bundle are again comprised of a multiple number of individual fibers, whose ends are distributed statistically or quasi-statistically over the entire light inlet surface, then the light in each light guide is guided by the entire inlet surface and no one place of the illuminated surface is then preferred over another. Further advantages of the invention will be clarified on the basis of an example of embodiment.

Light is emitted in the direction of an arrow (2) by a light source (1) and falls on a light inlet surface (3) of a bundle (4) of light guides [optical fibers] (5). One outlet light guide (6) is particularly emphasized in the drawing for purposes of

* Darkly shaded in the drawing—Translator's note.

explanation, although in the actual design, no one light guide is preferred over another. It is common to bundle light guides (5) closely together, so that practically no intermediate spaces are found between them. Here, the close bundling has been achieved by an elastic, cylindrical sheath (7), which solidly encloses the individual light guides and simultaneously prevents the entrance of light from the cylinder wall.

The individual light guides (5) terminate bluntly at the light inlet surface (3). This surface is smoothly polished, so that here only small losses are to be noted upon transfer of the light from one medium to the other. Despite the sheathing of light guides (5) by the sheath (7), this part of the spectral apparatus can still be moved. It has been attempted to present this movement by the curved form of bundle (4).

The bundle (4) of light guides (5) is introduced into a housing (8) not transparent to light. Inside housing (8), the outlet light guides are individually conducted to a plug-in frame (9). This plug-in frame (9) contains uptake holes corresponding to the number of light guides, in which light guides (5) are introduced for local securing. The underside of the plug-in frame is divided into individual chambers (11) in such a way that the light of two adjacent light guides cannot intermix. In each chamber, as in the chamber that is particularly emphasized, a pre-focusing lens (12), an interference filter (13) of a specific wavelength and a post-focusing

lens (14) are found successively in the beam path of the light fraction of a light guide. If a larger photocell is used, the post-focusing lens can be omitted. The end of the outlet light guide (6) is found in the focal point of the pre-focusing lens (12). In this way, it is achieved that interference filter (13) is irradiated with light directed to the optical axis. For irradiation with directed light of small aperture, interference filters have their defined transmission maximum, so that very pure light can be spectrally recorded behind interference filters (13). This light is focused by post-focusing lens (14) onto a light-sensitive surface of a receiver (15). This [post-focusing] lens can be omitted, if a photocell with large light-sensitive surface is used. Quantities to be measured corresponding to the spectral components of the light current fractions can be derived at electrical connections (16).

By using the post-focusing lens (14), it is achieved that receivers (15) can be made very small with respect to their geometric dimensions. These receivers then show only a very small electrical capacity and thus can be scanned very rapidly by sequential circuits. The interference filters (13) found in the different chambers (11) each have different spectral transmission, so that the quantities to be measured corresponding to the spectral components of the light of light source (1) are formed simultaneously at all light-sensitive receivers.

It is also favorable to provide several interference receivers of the same spectral transmission and to connect in parallel the light-sensitive receivers exposed to

the same radiation. Thus a simple amplification of the quantities to be measured in the very low-light spectral regions of the light can be achieved.

Alternatively or in addition to this, the individual light guides, however, can also be designed of different thicknesses, so that the light guides belonging to the low-light spectral regions have larger cross sections and thus also conduct more light. An enlarged representation of the light inlet surface (3) of bundle (4) of light guide (5) is given in Figure 2. Here, it will be illustrated on the example of light guide (6) that light guide (6), like the others also, is in turn comprised of individual fibers (17). These fibers are unwound [unbraided] and their ends are distributed over the entire light inlet surface. Since the fibers of the other light guides are also distributed over the entire surface, light from the entire irradiated light inlet surface is guided in each light guide. Each light-sensitive receiver thus finally receives light from all parts of the light inlet surface according to a statistical or quasi-statistical distribution. Figure 3 will illustrate how it is achieved by pre-focusing lens (12) that even in the case of oblique light incidence at the light inlet surface, the interference filter will be irradiated with directed light.

An oblique light incidence (18) with aperture (ω_1) and angle α of light incidence brings with it an also oblique light outlet (19) from the light guide under the angle α of light outlet and another aperture ω_2 . This will be illustrated by the oblique club of light (19). The pre-focusing lens, however, also deflects this light to a

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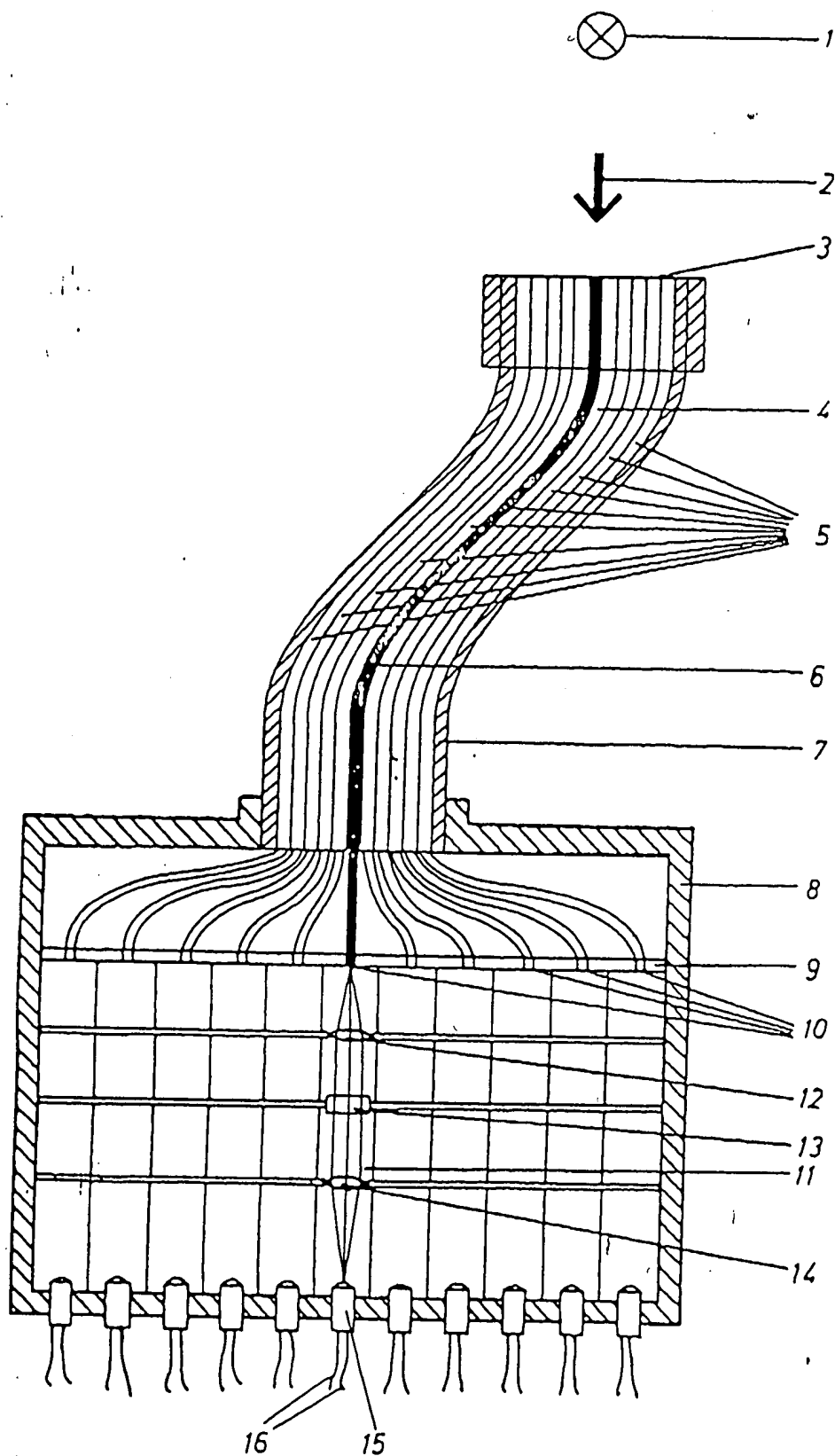


Figure 1

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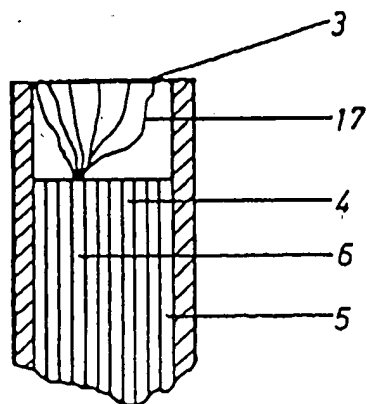


Figure 2

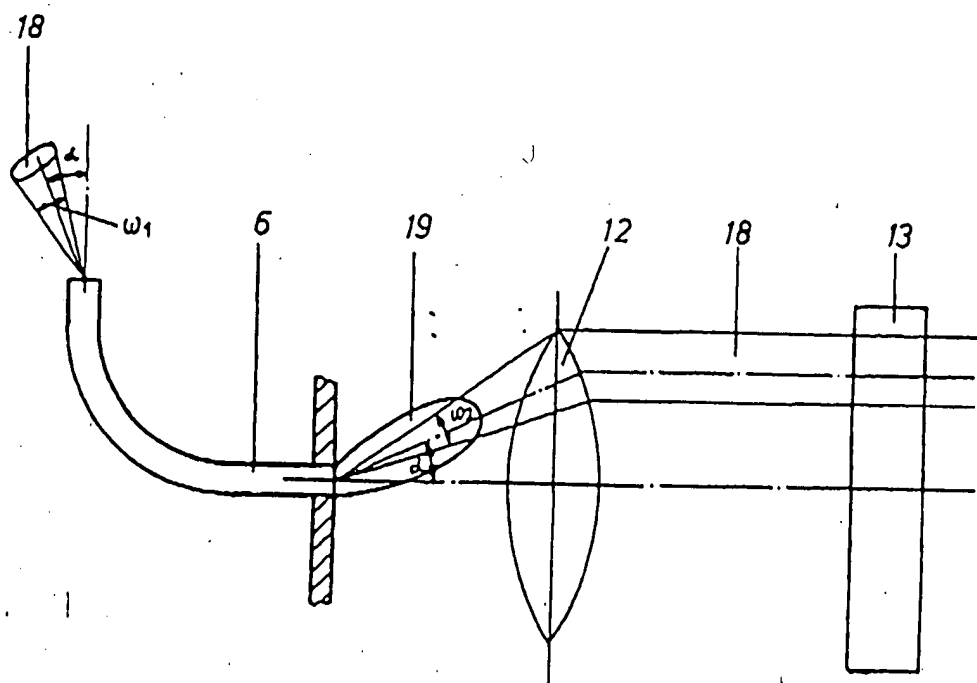


Figure 3

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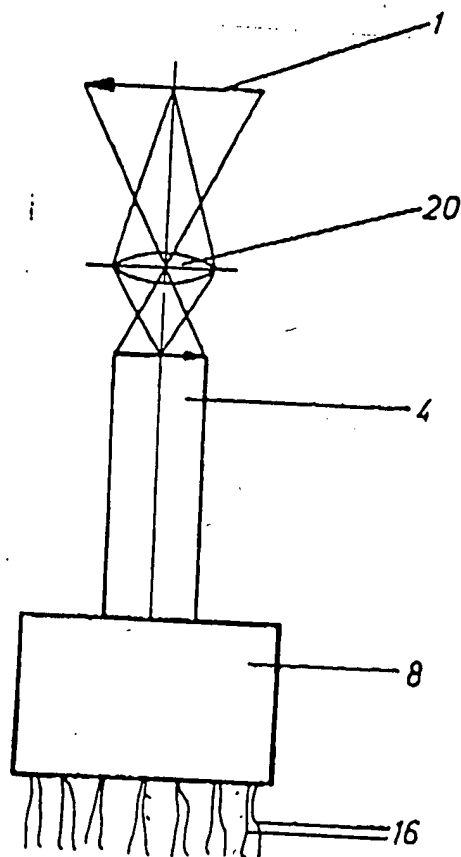


Figure 4